Wind Power: Performance & Economics

Wind Power on the Community Scale

Community Wind Power Fact Sheet # 2

RERL—MTC Community Wind Fact Sheet Series

In collaboration with the Massachusetts Technology Collaborative's Renewable Energy Trust Fund, the Renewable Energy Research Laboratory brings you this series of fact sheets about Wind Power on the community scale:

1. Technology
2. Performance
3. Impacts & Issues
4. Siting
5. Resource Assessment
6. Wind Data
7. Permitting

   Case Studies

Wind Power Performance, Economics, and Integration

This introduction to wind power technology is meant to help communities in considering or planning wind power. It focuses on commercial and medium-scale wind turbine technology that is available in the United States.

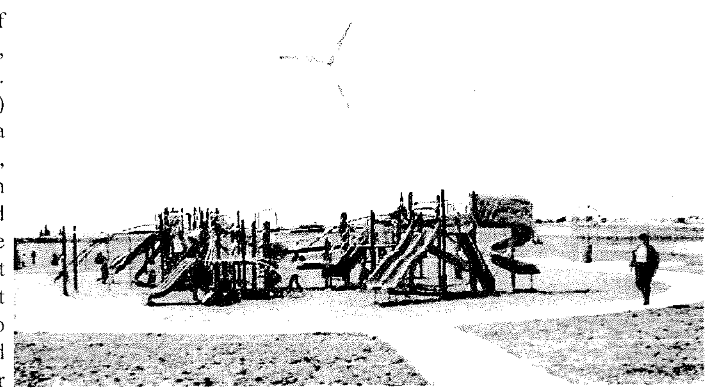
The focus of this series of fact sheets is medium- and commercial-scale wind.

This fact sheet also discusses the integration of wind power into the electrical grid, and the implications of wind power for the regional electrical system.

We also recommend a visit to a modern wind power installation – it will answer many of your initial questions, including size, noise levels, footprint, and local impact. A list of some of the nearest wind power installations is on the last page.

When the wind doesn't blow

A commercial-scale wind turbine delivers varying amount of electricity into the power grid, depending on the wind speed. Even though the power (kW) varies, every kWh it makes is a kWh that is not made by other, dirtier, sources. Experience in the US and around the world has demonstrated that while intermittency has some cost, it is a small percentage of the cost of producing electricity. Refer to supplemental Fact Sheet #2a, and Fact Sheet #1 on Technology, for more detail.



Community-owned wind power at the Spirit Lake, IA, elementary school

Capital Costs and Income

A brief introduction to making money from wind

A well sited and well planned community-scale wind installation in Massachusetts can make modest profits. This is a brief look at the costs and revenues involved in community wind projects.

Income Sources

A community that owns a medium- or commercial-scale wind turbine in New England has, in a sense, three potential income streams:

1. Use and/or sale of electricity (kWh)
2. Sale of Renewable Energy Certificates (REC's)
3. Federal production tax credit (PTC) or Renewable Energy Production Incentive (REPI), when available.

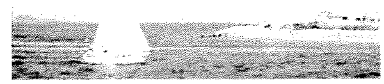
First, the energy (kWh) is sold or used. Energy used on-site is more valuable because it avoids buying energy at the retail price, which includes charges for transmission, distribution, etc. Any power that is not used on-site is sold on the market, typically under a contract referred to as a power purchase agreement, or PPA.

A second contract is needed to sell the Renewable Energy Certificates (REC's) that are "generated" along with the power.

Finally, a federal production incentive may offer either a tax credit or a payment of 1.5-1.8 ¢ / kWh.

Capital Costs

In Massachusetts, installed costs for commercial-scale turbines might be expected to be in the range of $1.2-1.5 Million/MW, i.e. a 1.5 MW machine might cost $2.25 M to purchase and install.

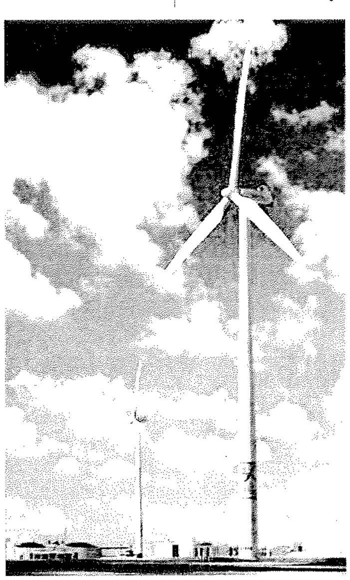


This town-owned wind turbine provides income for the town of Hull's municipal light company.

Energy Production Estimates

The amount of energy (MWh) that a wind turbine makes each year depends on many things, but the biggest factors are the wind speed at hub-height, and the size and type of turbine. This table gives a rough estimate of the amount of energy that a commercial-scale wind turbine could make. Use this information to estimate the impact of site choice (i.e. varying wind speeds) and turbine choice (e.g. varying sizes.) See the supplement, Fact Sheet 2a, for more discussion of capacity factor.

A variety of assumptions must be made to estimate capacity factors, so bear in mind that these are approximations and should be used only for comparison.



Community-owned wind turbines in Moorhed, MN

Annual avg. wind speed at hub height	Estimated Capacity Factor	Estimated MWh/yr per 1.5-1.8 MW turbine
6.0 m/s	22% - 25%	3,320 - 3,500
6.5 m/s	27% - 30%	3,920 - 4,190
7.0 m/s	31% - 34%	4,500 - 4,880
7.5 m/s	35% - 39%	5,150 - 5,540

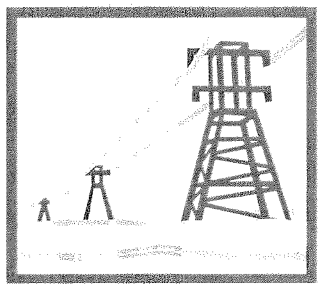
Assumptions used here: Based on manufacturer's data and manufacturer supplied power curves for commercial turbines available in the US in 1.5-1.8 MW size range. Other size turbines area available. Assume Rayleigh distribution, constant sea-level air density, etc. Assume 5% losses to account for unavailability, transformer losses, etc. Binning for estimates is conservative, i.e. based on the lower end of ranges. Note that when considering TrueWind mean speed estimates, they may be given at a hub height of 70 m. Taller and shorter towers are possible. Lower hub heights could result in a lower capacity factor.

Moorhead Minnesota, 750 kW NEG Micon Turbine. Picture credit: source: National Renewable Energy Laboratory, Photographic Information Exchange.

Wind Power on the Regional Electric Grid

<u>What is the grid?</u>

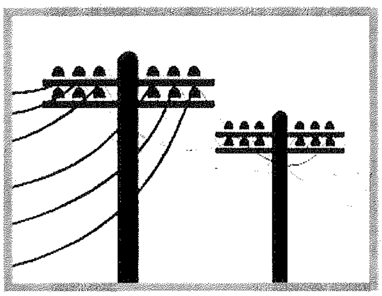
The grid is our regional electric system. The complex system consists of all the generators in a region, all the electric loads (such as lights, refrigerators, motors, etc.) and all the transmission and distribution power lines that connect them. The New England grid is managed by ISO New England (New England Power Pool) headquartered in Holyoke, MA.



<u>Transmission</u>

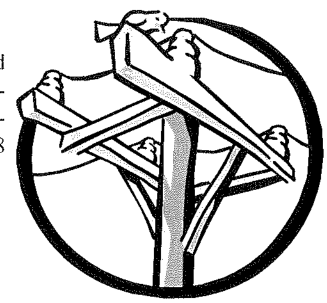
Power is transmitted long distances at high voltages then dropped down to medium voltages for local distribution.

Some typical transmission voltages are 115 kV (kilovolts) and 138 kV.



<u>Distribution</u>

Electricity is distributed locally at medium voltages. Some typical distribution voltages are: 13.8 kV, 34.5 kV, and 69 kV.



Grid Interconnection

The New England regional electric grid is a complex balance of millions of loads and thousands of generators. The electric loads fluctuate constantly, and at any given moment, the generators must deliver exactly the amount of power that the loads use.

Any commercial-scale wind turbine in New England will be connected to the grid. If only one or two turbines are installed at a site, their transformers may be connected into most points in the distribution network. A project with more than a few turbines will require the construction of a new substation. In either case, an interconnection study must be submitted to ISO-NE and the owners of the transmission or distribution lines at point of interconnection. A Facility Study then determines what, if any, additional electrical components are required for the transmission system. See Fact Sheet 7 (Permitting) for more on this application process.

Impact of Wind Power on the Grid

How are utilities reacting to wind power? How does it affect their operations?

A number of US utilities formed a consortium, the Utility Wind Interest Group (UWIG), to study the implications of increasing amounts of wind energy on the grid, including the impact of intermittency on day-to-day utility planning and load-following capability. A recent summary of their work concluded, "Work conducted to date has shown that wind power's impacts on system operating costs are small at low wind penetrations (about 5% or less). In most cases, these incremental costs would detract from the value of wind energy on current wholesale markets by 10% or less. At higher wind penetrations, the impact will be higher, although current results suggest the impact remains moderate with penetrations approaching 20%. While wind power does have some costs associated with grid operations, it also has some advantages from the utility's point of view, including short construction lead times, modularity, no emissions, and higher customer approval.

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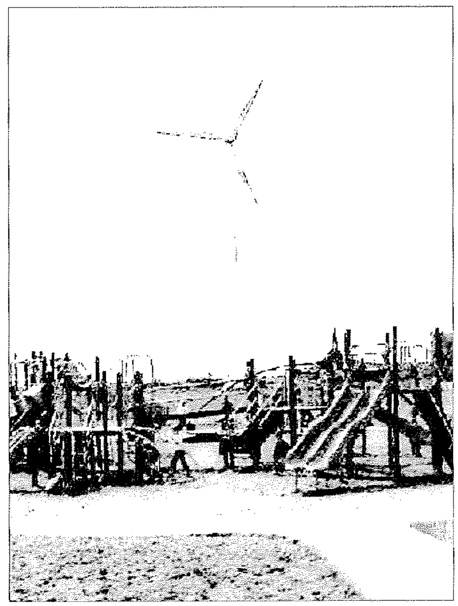
Community Wind: US Examples

Many towns are benefiting from community-owned or sponsored wind projects. Massachusetts does not have the broad expanses of land that some Western and Midwestern states do, so land-based wind power here is more likely to follow these examples of community-scale wind:

- Hull, MA: Municipal electric company owns Vestas V47, 660 kW: www.hullwind.org
- Mackinaw City, MI, leases town land to owner of two 900 kW turbines www.mackinawcity.org/
- Moorhead, MN: municipal utility owns 2, 750 kW turbines www.mpsutility.com/capture.htm
- Traverse City, MI: 660 kW, www.tclp.org/wind_brochure.pdf
- Worthington, MN, 4, 900 kW turbines www.riverwinds.biz/watch_us_grow1.htm
- Spirit Lake, IA school owns two turbines: www.spirit-lake.k12.ia.us/dist/wind/index.htm and www.greenpowergovs.org/wind/Spirit Lake case study.html
- Lac qui Parle, MN: the school district bought a 225 kW turbine in 1997 .
- Waverly Light & Power, IA operates 3 turbines http://wlp.waverlyia.com/search_wind.asp
- Kotzebue, AK: Kotzebue Electric Assoc. owns Atlantic Orient & NPS Northwind turbines.
- Forest City, IA, school owns 600 kW Nordex
- Blackfeet Nation, MT owns a Vestas V-17
- Rosebud Sioux, SD, 750 kW NEG Micon
- Pipestone School , MN, 750 kW NEG Micon
- Algona, IA municipal utility, 3 x 750 kW



Community-owned wind turbine at a school in Spirit Lake, IA

For More Information

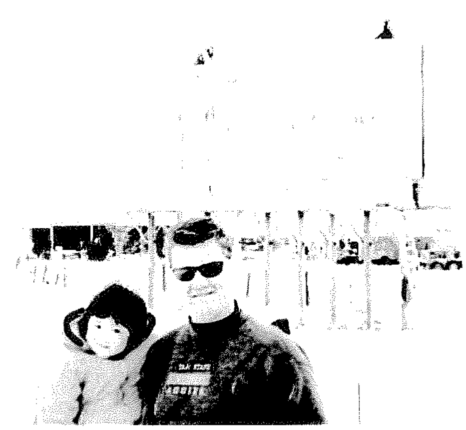
A thorough and accessible introduction to wind power technology, from the Danish Wind Industry Association: www.windpower.org/en/core.htm

Wind Energy Explained: Theory, Design and Application, Manwell, McGowan, & Rogers, Wiley, 2002

The Utility Wind Interest Group's Operating Impacts Studies analyze the costs and impacts of integrating wind power into the grid: www.uwig.org/operatingimpacts.html

For the on-line version of this fact sheet with live links, and the rest of the fact sheet series, see RERL's website: www.ceere.org/rerl/about_wind/

For links to more sources, see www.ceere.org/rerl/rerl_links.html



"Wind Power Can Fund Schools" campaign, Utah state energy office

Renewable Energy Research Laboratory, University of Massachusetts at Amherst

Wind Power: Capacity Factor, Intermittency, and what happens when the wind doesn't blow?

Wind Power on the Community Scale

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Introduction: the variability of wind

Wind turbines convert the kinetic energy in moving air into rotational energy, which in turn is converted to electricity. Since wind speeds vary from month to month and second to second, the amount of electricity wind can make varies constantly. Sometimes a wind turbine will make no power at all. This variability does affect the value of the wind power, but not in the way many people expect.

In this supplement to Fact Sheet 1, "Wind Power Technology", and Fact Sheet 2, "Performance and Economics", we give more precise definitions of a number of terms used in the wind power industry and the power generation industry in general. These concepts are important to understanding the integration of renewable energy onto the grid, and how we benefit from wind power, one of the lowest impact forms of electricity available to us today.

Capacity Factor is an indicator of how much energy a particular wind turbine makes in a particular place.

What is a "capacity factor" and why does it matter?

Definition:

Capacity factor is the ratio of the actual energy produced in a given period, to the hypothetical maximum possible, i.e. running full time at rated power.

Example:

Suppose you have a generator with a power rating of 1500 kW. Hypothetically if it ran at full power for 24 hours a days for 365 days, that would be:

(1500 kW) x (365 x 24 hours) = 13,140,000 kW-hr

in one year. Suppose that in fact it made 3,942,000 kWh in one year. Then in that year, the generator operated at a:

13,140,000 / 3,942,000 = 30%

capacity factor that year.

What are common values for capacity factor?

All power plants have capacity factors, and they vary depending on resource, technology, and purpose. Typical wind power capacity factors are 20-40%. Hydro capacity factors may be in the range of 30-80%, with the US average toward the low end of that range. Photovoltaic capacity factors in Massachusetts are 12-15%. Nuclear capacity factors are usually in the range of 60% to over 100%, and the national average in 2002 was 92%. The capacity factors of thermal plants cover a wide range; base-loaded thermal power plants (e.g. large coal) may often be in the range of 70-90%, and a combined cycle gas plant might be 60% depending

All power plants have a capacity factor

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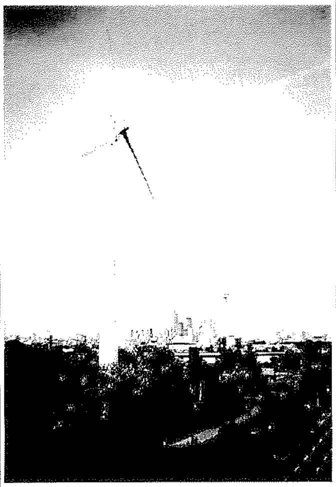

Urban-sited community wind, Toronto's WindShare project. (Photo courtesy Toronto Hydro)

Capacity Factor

continued from page 1

on gas prices, whereas power plants in the role of serving peak power loads will be much lower. One might expect a new biomass thermal plant to have an 80% capacity factor.

Is capacity factor the same as efficiency?

No, and they are not really related. Efficiency is the ratio of the useful output to the effort input – in this case, the input and the output are energy. The types of efficiency relevant to wind energy production are thermal, mechanical and electrical efficiencies. These efficiencies account for losses, most of which turn into heat in the atmosphere and water. For instance, the average efficiency of the US electricity generation infrastructure is about 35% – this is because in most thermal plants, about two thirds of the input energy is wasted as heat into the environment. The mechanical conversion efficiency of commercial wind turbines is a fairly high, in the range of 90%.

Capacity Factor is not an indicator of efficiency.

Wind power plants have a much lower capacity factor but a much higher efficiency than typical fossil fuel plants. A higher capacity factor is not an indicator of higher efficiency or vice versa.

Is a higher capacity factor "better"?

Within a given technology or a given plant, yes, you can generally say that a higher capacity factor is better and in particular, more economical. But it does not make sense to compare capacity factors across technologies, because the economics of both production and capacity are so different from one technology to the next – the capacity factor is just one of many factors in judging if a power plant is feasible. Instead, more useful is to compare the cost of producing energy among the various technologies.

Intermittency, and the value of wind power

The wind does not always blow; sometimes a wind power plant stands idle. Furthermore, wind power is really not "dispatchable" – you can't necessarily start it up when you most need it. As wind power is first added to a region's grid, it does not replace an equivalent amount of existing generating capacity – i.e. the thermal generators that already existed will not immediately be dismantled.

Wind power is by nature intermittent

Does intermittency imply that wind power cannot have beneficial impact on the environment?

No. We need to distinguish here between capacity and production. The first is the amount of installed *power* in a region, and is measured in MW. Production is how much *energy* is produced by that capacity, and is measured in MWh.

While wind power does not replace an equal amount of fossil-fuel *capacity*, it does replace *production* – for every MWh that is produced by a wind turbine, one MWh is *not* produced by another generator. The damage done by our existing electricity generation is primarily a function of production, not capacity. Burning less coal has a positive environmental impact, even if the coal plant is not shut down permanently.

In Massachusetts, the avoided production would mostly be from fossil-fuel plants. So for every MWh that is produced by a wind turbine here, that causes about two thirds of a ton of CO_2 not to be produced (see page 4 for a discussion of marginal emissions in New England.)

The impact of intermittence on the grid

Intermittency does have an impact on the grid, though it is not the impact that wind power critics usually assume. When the concentration of wind power in a region is low, the impact is negligible. Keep in mind that loads fluctuate constantly, so a small amount of

Continued on next page...

Intermittency

continued from page 2

fluctuating generation can be said to act as a "negative load" and have almost no measurable impact on the grid. Many modern wind turbines can supply some grid support as well (referred to as "ancillary services," e.g. voltage support), just as most power plants do. As the concentration of wind power increases in a region, though, intermittence and the difficulty of forecasting wind power production do have a real cost associated with them.

For every MWh that is produced by a wind turbine, one MWh is not produced by another generator.

Recent studies of wind power installed on United States grids have attempted to determine the actual cost of intermittency, They indicate it is currently in the area of a 2-5 tenths of a cent per kWh, depending on penetration. The higher costs were for 20% penetration. A few tenths of a cent per kWh is not insignificant, but it is still a small percentage of the total cost of generating power (which for wind power might be in the range of 2-6 ¢/kWh). Intermittency does impose a cost but that cost is typically not prohibitive, as some people imagine.

Will wind power ever make all our electricity?

There are places in the world where wind power provides nearly all of the electric power used. These high-penetration wind grids tend to be in remote areas. While high-penetration wind systems are not impossible, no one is suggesting that we will make the bulk of New England's power with wind in the near future.

Today, Denmark and northern Germany are the examples of large-scale grids with the highest penetration of wind power. Though more densely populated than New England and not particularly more windy, they produce about 20% of their energy from the wind. Wind power is a proven generation technology that is working in today's electrical grids around the world.

The need for back-up generation

Wind power plants have been installed in the United States for long enough that detailed studies have been completed on the impacts and costs of its intermittency. A recent study concluded that,

"...the results to date also lay to rest one of the major concerns often expressed about wind power: that a wind plant would need to be backed up with and equal amount of dispatchable generation. It is now clear that, even at moderate wind penetrations, the need for additional generation to compensate for wind variations is substantially less than one-for-one and is often closer to zero."

- Utility Wind Interest Group (UWIG) "Wind Power Impacts on Electric-Power-System Operating Costs, Summary and Perspective on Work Done to Date, November 2003"

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Availability, Reliability,
& some other terms defined

The discussion of wind power's capacity factor and intermittency often brings up other terms that bear defining.

Reliability
Modern commercial wind power plants are fairly reliable, which is to say, they are not shut off for maintenance or repairs very much of the time. "Dispatchability" is not synonymous with "reliability".

Dispatchability
Dispatchability is the ability of a power plant to be turned on quickly to a desired level of output. Wind power plants are not dispatchable.

Availability
All power plants must be taken down for maintenance, both scheduled and, at times, unscheduled maintenance. The percentage of time that a wind power plant is not down for maintenance and is able to operate is called its availability. Because the wind isn't always blowing, the percentage of time that the machine is actually producing electricity will be lower than the availability. Modern wind turbines may have a guaranteed availability of 95% while under warranty.

Penetration
Wind power penetration is the amount of energy produced by wind power, as a percentage of total energy used, in a given region. In the United States as a whole, the wind power penetration is a small fraction of a percent.

Marginal emissions
Each year the operator of our electric grid, ISO New England Inc., analyzes and reports on the marginal emissions rate for our region. "Marginal" means the change in emissions that would occur if one more or one fewer MWh were generated. These figures are specifically intended to be an indicator of the value of conservation, efficiency, and renewable energy.

For instance, the annual marginal average emissions rates for 2002 were:

Pollutant	A major impact of this pollutant	Marginal emissions rate
SO_2	Acid rain	3.27 lbs/MWh
NO_X	Smog, asthma	1.12 lbs/MWh
CO_2	Global climate change	1337.8 lbs/MWh

So for instance, one wind turbine rated at 660 kW with a 28% capacity factor (i.e. about 1.5 million kWh/year) eliminates the production of about:

Pollutant	Emissions avoided
SO_2	5,300 lbs
NO_X	1,800 lbs
CO_2	1,100 tons

These numbers are the annual averages; see the full ISO New England report for a more complete discussion of regional, seasonal, and time-of-day variations.

For More Information

The Utility Wind Interest Group's Operating Impacts Studies analyze the costs and impacts of integrating wind power into the grid: www.uwig.org/operatingimpacts.html

Danish Wind Industry Association: thorough and very accessible technical information: www.windpower.org

Wind Energy Explained: Theory, Design and Application, Manwell, McGowan, & Rogers, Wiley, 2002

ISO New England's 2004 Marginal Emissions Rate analysis is available at www.iso-ne.com/genrtion_resrcs/reports/emission/2004_mea_report.pdf

For the on–line version of this Fact Sheet with the complete set of links, see RERL's website: www.ceere.org/rerl/about_wind/ . Here you will also find links to Fact Sheets 1 and 2, "Wind Power Technology" and "Performance and Economics," which include an introduction to wind power and many of the concepts used above (e.g. energy vs. power, and the grid.)

For links to more sources of information, see www.ceere.org/rerl/rerl_links.html

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The Effect of Wind Speed and Electric Rates On Wind Turbine Economics

Economics of wind power

This is an introduction to the economics of community-scale wind power projects. Wind energy projects are highly sensitive to many factors – particularly wind speed, and its close relative, capacity factor. First, start with two definitions.

Definition: Capacity Factor

"Capacity Factor" is equal to the annual energy production divided by the theoretical maximum energy production if the generator were running at its rated power all the year. For example, if a 1500 kW machine makes 3.5 million kWh in a year, that's 3,500,000 / (365*24 * 1500) = 27% capacity factor. (See Fact Sheets on RERL's website for more on Capacity Factor.)

Your capacity factor depends mainly on the wind speeds and the turbine make and model.

Definition: Simple Payback

The "Simple Payback" time of a project is found by taking the initial cost of putting a machine in, and dividing by the annual net income. It is a simple indicator of how long it takes to get out the money you put in. It does not reflect the cost of money.

Example

The following page outlines a simple example of the simple payback period of a small wind power project. All the figures are *per turbine*, so it can be used for a one, two or three-turbine project.

This simplified example is intended only for illustrative purposes. It includes many assumptions for costs, revenues, turbine size, etc. – your case will be different. This short document does not tell you *what* these costs will be, but gives you a framework to estimate project payback – once you have evaluated all the assumed values for your particular case. The following notes apply:

1. *Net Annual income (line T) is NOT profit! It is an estimate of income after operating expenses, but before the cost of capital, interest, etc.. That is, this would be the money that is used to pay for the capital equipment plus interest - and hopefully, some profit ultimately as well.*
2. *Land lease payments, if any, can be included in the annual cost (line S)*
3. *All figures are per turbine, yet costs will vary based on the number of turbines in a project*
4. *Since the federal tax credit lasts only 10 years, any examples showing a simple payback of over 10 years falsely inflates the annual revenue afterwards.*

What to notice in the example - Ways to reduce the payback time:

1. Raise Production (line E) – make more energy (kWh), i.e., better capacity factor: find higher wind speeds, use a taller tower, a better site, a different turbine.
2. Raise Revenue (line P) – get better value for your kWh: use more power on-site.
3. Lower Costs (line V) – keep installation cost/kW down: put in more turbines, chose a simpler site.

Example The economics of a wind power project depends on many factors. Here is a simple example using some broad assumptions:

		Value	Units
1. Production	Capacity factor:	***28.0%***	
per turbine	Rated Power per turbine:	1,500	kW
	Availability	97%	
		8,760	hrs/year
	Annual Energy Production	3,568,824	kWh/year
2. Revenue	Energy used on-site (%)	**50%**	
per turbine	Your electricity price	$0.150	$/kWh
	Energy price (when sold wholesale)	$0.050	$/kWh
	Energy value	$0.100	$/kWh
	Massachusetts RPS (REC's)	$0.030	$/kWh
	Federal tax credit (PTC) (1st 10 years only)	$0.019	$/kWh
	Revenue Rate, Gross (per kWh)	$0.149	gross rev/kWh
	Estimated Annual revenue	$531,755	gross $/yr
3. Costs	Maintenance & insurance (rate)	$0.015	$/kWh
per turbine	Annual costs	$53,532	$/year
	Estimated annual income*	$478,222	net $/yr
	Estimated installed cost/ MW	***2,000***	$/kW
	Estimated installed cost	$3,000,000	installed cost
***4. "Simple Payback"** period, per turbine**		6	years

Important ways to reduce payback time

Using all the above assumptions, we can estimate "Simple Payback" as a function of capacity factor and revenue rate for this example case. The purpose of this table is not to show payback – your results will vary – but rather to illustrate the importance of wind speed (left column) and on-site loads (top row) to the economics of community-scale wind power.

		Gross revenue rate per kWh for this example project:																
Cap. Factor:	kWh/year	5 ¢	6 ¢	7 ¢	8 ¢	9 ¢	10 ¢	11 ¢	12 ¢	13 ¢	14 ¢	15 ¢	16 ¢	17 ¢	18 ¢	19 ¢	20 ¢	21 ¢
18%	2,294,244	37	29	24	20	17	15	14	12	11	10	10	9	8	8	7	7	7
20%	2,549,160	34	26	21	18	16	14	12	11	10	9	9	8	8	7	7	6	6
22%	2,804,076	31	24	19	16	14	13	11	10	9	9	8	7	7	6	6	6	5
24%	3,058,992	28	22	18	15	13	12	10	9	9	8	7	7	6	6	6	5	5
25%	3,186,450	27	21	17	14	13	11	10	9	8	8	7	6	6	6	5	5	5
26%	3,313,908	26	20	16	14	12	11	10	9	8	7	7	6	6	5	5	5	5
27%	3,441,366	25	19	16	13	12	10	9	8	8	7	6	6	6	5	5	5	4
28%	3,568,824	24	19	15	13	11	10	9	8	7	7	6	6	5	5	5	5	4
29%	3,696,282	23	18	15	12	11	10	9	8	7	6	6	6	5	5	5	4	4
30%	3,823,740	22	17	14	12	10	9	8	7	7	6	6	5	5	5	4	4	4
31%	3,951,198	22	17	14	12	10	9	8	7	7	6	6	5	5	5	4	4	4
32%	4,078,656	21	16	13	11	10	9	8	7	6	6	5	5	5	4	4	4	4
33%	4,206,114	20	16	13	11	10	8	8	7	6	6	5	5	5	4	4	4	4
34%	4,333,572	20	15	13	11	9	8	7	7	6	6	5	5	4	4	4	4	4
35%	4,461,030	19	15	12	10	9	8	7	6	6	5	5	5	4	4	4	4	3
36%	4,588,488	19	15	12	10	9	8	7	6	6	5	5	5	4	4	4	4	3
38%	4,843,404	18	14	11	10	8	7	7	6	5	5	5	4	4	4	4	3	3

* Many assumptions go into these examples.

Renewable Energy Research Laboratory, University of Massachusetts at Amherst

Wind Power: Interpreting your Wind Resource Data

Wind Power on the Community Scale

Community Wind Power Fact Sheet # 6

RERL—MTC Community Wind Fact Sheet Series

In collaboration with the Massachusetts Technology Collaborative's Renewable Energy Trust Fund, the Renewable Energy Research Laboratory brings you this series of fact sheets about Wind Power on the community scale:

1. Technology
2. Performance
3. Impacts & Issues
4. Siting
5. Resource Assessment
6. Wind Data
7. Permitting

Case Studies

Overview

This document will help you understand the statistics commonly used to describe wind when it is studied for the purpose of evaluating wind power facilities.

Wind Statistics

1. **Long-term mean wind speed:** Often given as the annual mean (average) wind speed, this number represents the quality of the wind resource.

Long-Term Mean Wind Speed		Relative Quality of Wind Resource for Commercial Turbines*
m/s	mph	
0 - 6	0 - 13.5	0 - 73%
6 – 7	13.5 – 15.8	73 - 100%
7 – 8	15.8 – 18	100 - 125%
> 8	> 18	125 % & above

** Based on typical annual energy production at 6, 7 and 8 m/s annual averages, as a percentage of production at 7 m/s. Note that quality will vary with other factors that affect project economics.*

The power in the wind is related to the cube of the wind speed, so a small improvement in resource quality results in a large increase in electrical power.

2. **Prevailing wind direction:** The direction from which the wind blows most often is the prevailing wind direction. Knowing the directional behavior of the wind is useful when considering where to install wind turbines. If the prevailing winds come from the west, for example, you would not want to install a turbine somewhere with an obstacle to the west.

3. **Average turbulence intensity:** Turbulence intensity is a measure of the "gustiness" of the wind and is calculated as the standard deviation (over a short interval, e.g. 10 minutes) of the wind speed divided by the mean wind speed. Lower turbulence results in less required maintenance and better performance from a wind turbine. Average turbulence intensities are used to compare different sites. In New England, turbulence intensities range from 0.1 to 0.5. Offshore values may be even lower. Further discussion is found in the Graphs section below.

4. **Wind shear:** Usually, wind speeds increase with height above the ground. This change in wind speed with height is called wind shear. Wind shear can be characterized by the exponent, α, in the so-called "power law" equation: where V is the wind speed at the height (z) of

$$V = V_{ref}\left(\frac{Z}{Z_{ref}}\right)^{\alpha}$$

interest (say, hub height), and V_{ref} is the speed actually measured at another height z_{ref}. The larger the shear, the more the wind speed increases at higher elevations.

5. **Data quality:** When collecting data, it is important to know the quality of the data. Poor quality data are not trustworthy. Two numbers often reported are:

- *Gross data recovery percentage:* The percentage of data expected which were actually recorded in the logger.
- *Net data recovery percentage:* The percentage of data expected which passed a quality control process. Differences between the gross and net percentages are usually due to sensor icing or malfunction.

Wind speeds are usually measured in units of meters per second (m/s).

1 m/s = 2.25 mph

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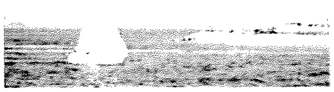
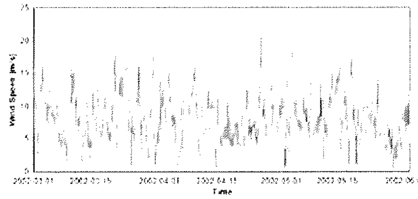


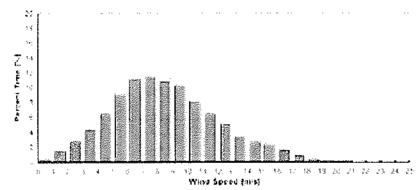
Community-owned wind turbine in Hull, MA.

Graphs

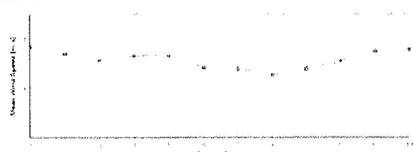
Wind speed time series: This graph shows trends and the variability of the wind.



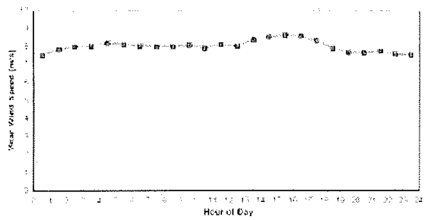
Wind speed distribution: This shows the percentage of time that the wind blew at a given speed. The highest percentage indicates the wind speed most often experienced. This may be different than the mean wind speed.



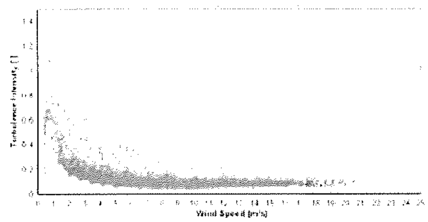
Monthly average wind speeds: This plot of the monthly average wind speeds shows the trends in the wind speed over the year. New England winds are usually faster in the winter and slower in the summer.



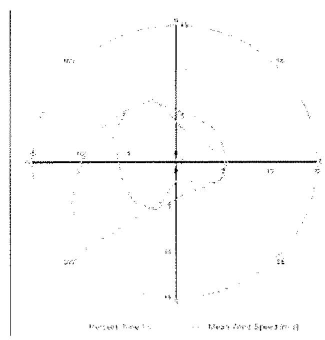
Diurnal average wind speeds: This plot shows the average wind speed for each hour of the day. The typical diurnal pattern at low elevations in New England is low speeds in the morning, winds increasing through the afternoon, then subsiding at night. While this pattern usually exists throughout the year, the specific times of day at which the highs and lows occur will vary from season to season.



Turbulence intensity: This graph shows the gustiness of the wind at different wind speeds. Together with the Wind Speed Distribution, this graph can be used to determine the level of turbulence present under typical operating conditions. A turbine manufacturer will use this graph to predict maintenance scheduling.



Wind rose: A plot, by compass direction, showing the percentage of time that the wind comes from a given direction and the average wind speed in that direction. This plot is used to determine how to orient and space a group of turbines.



For More Information

Another model of wind shear, as explained by the Danish Wind Industry Association: www.windpower.org/en/tour/wres/shear.htm

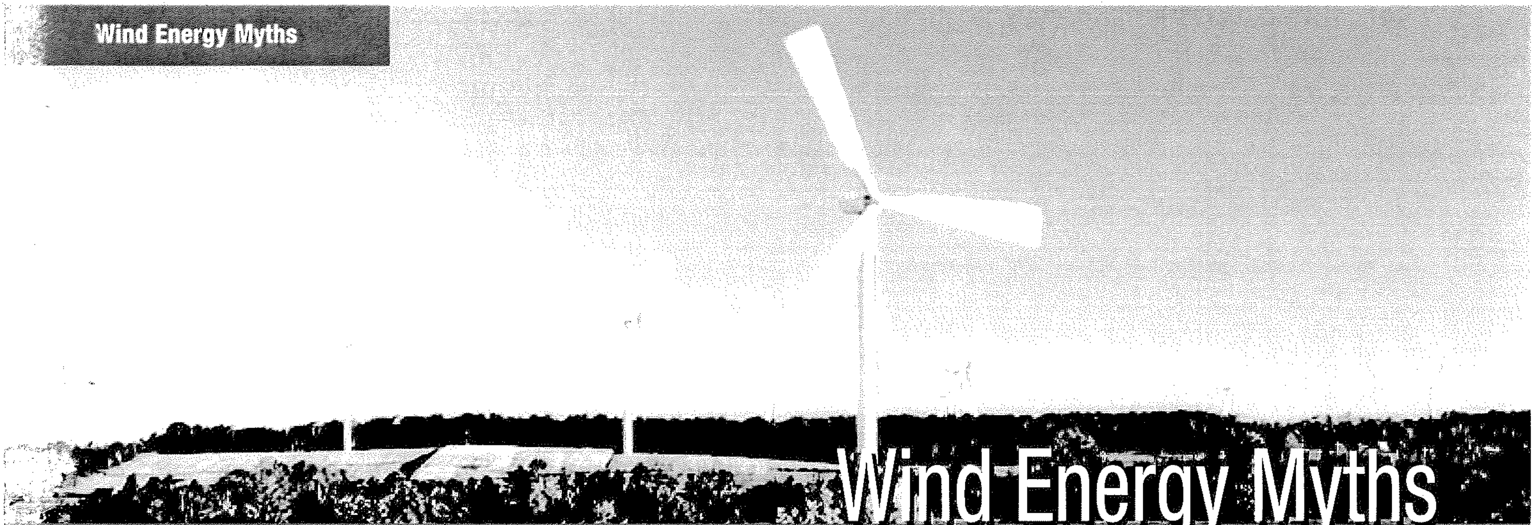
New England wind resource map by TrueWind: truewind.teamcamelot.com/ne/

American Wind Energy Association's wind resource info: http://www.awea.org/faq/basicwr.html

National Wind Technology Center's wind resource information list: http://rredc.nrel.gov/wind/

Wind Energy Explained, Theory, Design and Applications, Manwell, McGowan, Rogers, Wiley, 2002

For the on-line version of this fact sheet with the complete set of links, see www.ceere.org/rerl/about_wind/



Wind Energy Myths

Wind Powering America Fact Sheet Series

1 Wind energy is more expensive than conventional energy. Wind's variability does increase the day-to-day and minute-to-minute operating costs of a utility system because the wind variations do affect the operation of other plants. But investigations by utility engineers show these costs to be relatively small—less than about 2 mills/kilowatt-hour (kWh) at penetrations under 5% and possibly rising to 5 mills at 20% penetration. In fact, when the Colorado Public Service Commission issued a ruling in 2001 on the 161-megawatt (MW) wind project in Lamar, Colorado, the commission determined that wind energy provided the lowest cost of any new generation resource submitted to an Xcel Energy solicitation bidding process (except for one small hydro plant). The commission also noted that unlike the other generation resources considered, the Lamar project avoided the risk of future increased fuel prices.[1] And in a recent landmark study of wind integration into the New York State electric power system, a 10% addition of wind generation (3,300 MW of wind in a 34,000-MW system) actually projected a reduction in payments by electricity customers of $305 million in one year.[2]

Craig Cox, Interwest Energy Alliance/PIX11929

When the Colorado Public Service Commission issued a ruling in 2001 on the 161-MW wind project in Lamar, Colorado (pictured above), the commission determined that wind energy provided the lowest cost of any new generation resource submitted to an Xcel Energy solicitation bidding process (except for one small hydro plant).

2 Wind energy requires a production tax credit (PTC) to achieve these economics. True, but every energy source receives significant federal subsidies; it is disingenuous to expect wind energy to compete in the marketplace without the incentives enjoyed by established technologies.[3]

3 The production tax credit and accelerated depreciation are helpful only to big, out-of-state developers. The economic benefits aren't local, and rural electric cooperatives and municipal utilities can't receive the same benefits. It's true that only entities that pay federal taxes can use the tax credits to reduce their tax liability. But those tax credits result in lower wind energy costs for the benefit of all electricity customers. However, if local entities assume equity positions in wind plants, then they can receive the tax credit benefits. Whether or not the wind-plant equity is locally held, wind plants result in jobs for the local community and the need for local services—both during construction and during operation. Additionally, the added county and state taxes and the landowner lease payments directly benefit the local and state economies. And to the extent that debt financing comes from local sources, debt-service payments stay within the local community.

Also, in some cases farmers have joined together in a cooperative arrangement to build and own wind plants. In aggregate, their tax liability can be sufficient to make full use of the tax credits.[4]

4 Wind energy is unpredictable and must be "backed up" by conventional generation. No power plant is 100% reliable. During a power plant outage—whether a conventional plant or a wind plant—backup is provided by the entire interconnected utility system. The system operating strategy strives to make best use of all elements of the overall system, taking into account the operating characteristics of each generating unit and planning for contingencies such as plant or transmission line outages. The utility system is also designed to accommodate load fluctuations, which occur continuously. This feature also facilitates accommodation of wind plant output fluctuations. In

Denmark, Northern Germany, and parts of Spain, wind supplies 20% to 40% of electric loads without sacrificing reliability. When wind is added to a utility system, no new backup is required to maintain system reliability.

5 **If wind energy displaces energy from existing coal plants, then rates will go up.** Rates for electricity from wind plants being installed today are comparable to wholesale electric power prices of 2.5¢ to 3.5¢/kWh. The incremental cost of wind power, if any, will be negligible when distributed among all customers. A number of studies have examined the rate impacts of wind and have considered the costs of various renewable portfolio standard percentages from 5% to 10%, and average residential bill impacts are predicted to range from a savings to a premium of 25¢/month. In fact, some studies predict the accompanying decrease in demand for conventional fuels will reduce fuel prices enough to fully compensate for slightly higher costs for renewables. In the New York study mentioned above, wind displaced energy from both coal and natural gas plants. Rates decreased, and harmful emissions from the coal and gas plants were reduced as well.[5]

6 **New natural gas power plants provide cheaper energy than wind plants.** This is not likely with today's rising gas prices. At \$3/MBTU, the fuel cost alone is 2.5¢ to 3¢/kWh, and capital and O&M costs add a similar amount. Today, gas prices have risen to more than \$6/MBTU, yielding a fuel cost alone in the 5¢ to 6¢/kWh range. And gas prices have spiked to more than \$10/MBTU in past years. Betting on low gas prices over the foreseeable future is highly risky, while energy costs from wind plants will be relatively stable over time. In a recent study, Lawrence Berkeley National Laboratory found that the natural gas "hedge value" of wind could be conservatively estimated to be 1/2 cent/kWh.[6,7]

7 **Large, utility-grade wind turbines can't be installed on the distribution grid without expensive upgrades and power-quality issues.** In situations with weak distribution grids (long lines with thin wires and few customers—maybe even single-phase), this can be true. However, in many cases wind generation can be connected to the distribution system in amounts up to about the rating of the nearest substation transformer. One study of a rural Midwestern county estimated that several tens of megawatts of turbines could be installed on the local distribution grid with a minimum of upgrade expense and minimal power-quality impacts. A number of single wind turbines and clusters of turbines are currently connected to the distribution system.[8]

8 **Small projects that might be suitable for co-ops or small municipal utilities are not economical.** Small projects generally have a higher cost per megawatt than larger wind plants, as would be expected. However, the incremental costs on customers' bills are likely to be small. The energy premium for a small project is unlikely to exceed 50%. If the project provides a small portion of the community's needs—say 2%—then the premium is reduced to about 1% if distributed among all customers. Some communities view this premium as a worthwhile investment to obtain local environmental benefits and experience with wind power.

9 **Wind turbines kill birds and thus have serious environmental impacts.** Bird kills have caused serious scientific concern at only one location in the United States: Altamont Pass in California, one of the first areas in the country to experience significant wind development. Over the past decade, the wind community has learned that wind farms and wildlife can and do coexist successfully. Wind energy development's overall impact on birds is extremely low (<1 of 30,000) compared to other human-related causes, such as buildings, communications towers, traffic, and house cats. Birds can fly into wind turbines, as they do with other tall structures. However, conventional fuels contribute to air and water pollution that can have far greater impact on wildlife and their habitat, as well as the environment and human health.

10 **Wind turbines are noisy.** Modern wind turbines produce very little noise. The turbine blades produce a whooshing sound as they encounter turbulence in the air, but this noise tends to be masked by the background noise of the blowing wind. An operating modern wind farm at a distance of 750 feet to 1000 feet is no more noisy than a kitchen refrigerator.

You can find more information on wind energy myths at www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/wpa/34600_misconceptions.pdf

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1 www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/xcel_wind_decision.pdf

2 www.nyserda.org/publications/wind_integration_report.pdf

3 For more on energy subsidies, visit www.earthtrack.net

4 Mark Bolinger, A Survey of State Support for Community Wind Power Development (http://eetd.lbl.gov/ea/EMS/cases/)

5 www.nyserda.org/publications/wind_integration_report.pdf

6 http://eetd.lbl.gov/ea/ems/reports/56756.pdf

7 Alan Greenspan, Federal Reserve Chairman, testimony at Senate committee hearing, July 10, 2003

8 Distributed Wind Power Assessment, National Wind Coordinating Committee, February 2001, available at www.nationalwind.org

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WIND POWERING AMERICA

A Strong Energy Portfolio for a Strong America
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Wind Power: Impacts and Issues

Wind Power on the Community Scale

Community Wind Power Fact Sheet # 3

RERL—MTC Community Wind Fact Sheet Series

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1. Technology
2. Performance
3. Impacts & Issues
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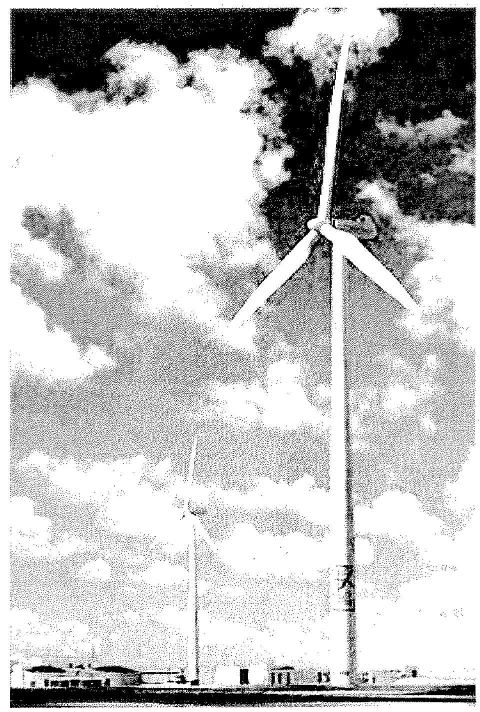
7. Permitting

   Case Studies

Energy Matters

The production and use of energy has more impact on the environment than any other human activity. Wind power is considered one part of the solution to this issue because it is one of the lowest–impact forms of electricity available to us. Still, it does affect the natural and human environment.



Wind power raises interesting ethical questions because while the benefits of clean power are global and regional, the impacts are local. Local decisions about wind power must be made with these global issues in mind.

The main impacts of wind power are visual, auditory, and wildlife effects. This Fact Sheet introduces information on the form and extent of these impacts. It also lists some of the impacts of fossil-fuel-generated electricity for comparison. Sources for more in–depth information are also offered on the last page.

Why Wind Power?

Wind power is the world's fastest growing electric power source because it makes clean, emission–free power and is increasingly economical.

Making electricity is the largest source of US industrial air pollution today, according to the EPA. In the US, power plants make 1/3 of greenhouse gas CO_2 emissions in the US, 1/4 of the smog– and asthma– causing NO_x, and 2/3 of acid-rain-producing SO_2. Coal plants emit significant amounts of mercury and dioxin into the air; mercury, for instance, accumulates in fish, and causes brain damage in children, and dioxin causes cancer. Mining and drilling of fossil and nuclear fuels scars vast areas of land in the US and around the world. The environmental and health impacts of our electricity today are real and serious issues.

Renewable energy is one of the primary tools to combat the impacts of our energy use, and wind power is one of the few renewable energy technologies that is feasible for widespread use today and in the near future.

For more details on the impacts of our electricity generation, see page 4.

Land Use, and Wind Power's Impacts on the Natural Environment

Other than the impact on birds and bats discussed on below, the negative environmental impacts of wind power come from the change in habitat that results from the clearing of the land.

The focus of this series of Fact Sheets is medium– and commercial–scale wind power.

Land use requirements: The direct footprint of a wind turbine is relatively small—the base of the tower is typically about fifteen feet across. The immediately surrounding area must be kept free of trees. Power lines are buried in the immediate area, but remote locations may require overhead lines elsewhere, which require clearing.

Spacing: Wind turbines must be spaced at least 2-5 rotor diameters apart to avoid reduced performance and increased wear. This translates to a typical spacing of between 500 and 1000 feet along a ridge line for a full-scale wind turbine.

See Fact Sheet 4, "Siting in Communities" for more discussion on wind turbine siting.

Birds, Bats and Wind Power

While it is easy to conjure images of large wind turbines harming small birds, in fact this is not the problem that many people imagine. Modern wind turbines kill on average one to two birds per turbine, per year. With proper siting, these risks can often be reduced further.

Bat collisions have not been quantified as thoroughly, but so far bats do not appear to be at greater risk than birds.

The bird collision problems that arose at Altamont Pass, CA in the turbines from the 80's and 90's, have been exhaustively studied by biologists; the risk factors they identified (see table on page 2) largely do not exist in New England, and the problem has not arisen to the same magnitude elsewhere in the US.

A Phase One Avian Risk Assessment Study, performed by wildlife biologists looks at the avian collision risk factors discussed in the table below. In weighing the risks and benefits of a wind plant, against the "no–action option" – i.e. no wind turbines – is not benign; it also carries inherent risks to birds (and the rest of us) as well, though the broad risks to birds of fossil fuel combustion has not been as well quantified.

Avian Collision Risk Factors

(source: Kerlinger & Curry)

#	Known or Suspected Risk Factors for avian collision	Altamont Pass, California	Typical Modern Wind installation in New England
1	Large concentrations of turbines	5,400 (in 2001)	1–40
2	Lattice towers allow raptors to perch	Lattice	Tubular towers do not attract perching
3	Fast Rotating Turbine Blades	50–72 rpm	Slow Rotating Blades ~12–18 rpm
4	Closely Spaced Turbines	80–100 feet (<30 m)	Widely Spaced Turbines >650+ feet (>200 m)
5	Turbines in Steep Valleys or Canyons	Steep Valleys & Canyons	Turbines on flat terrain, rolling hills, or ridge tops (no steep hills except sides of ridges)
6	Prey base to attract raptors	Large	*
7	Raptor & Susceptible Species	Present	*
8	FAA lighting attracting night–migrating birds	Often unlit	Risk is present and may account for the majority of night–time avian collisions with modern turbines.

* The magnitude of these risks at a particular site would be addressed in a phase 1 avian risk study

Impacts on the Human Environment

Visual

The primary impact of wind power is visual. Because wind turbines must be exposed to the wind, they are usually in prominent locations.

Aesthetic considerations are impossible to quantify and difficult to discuss. Some people like seeing wind turbines; some people don't. The question of whether a community is willing to accept a visual impact in return for making clean power is an issue for public policy and planning.

FAA Lighting

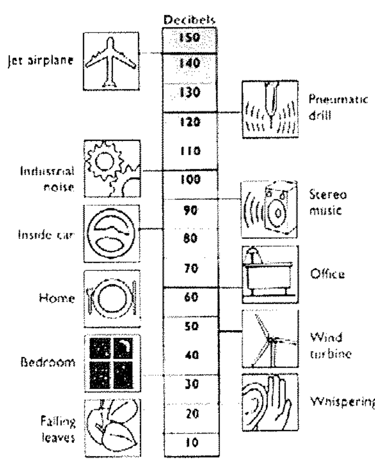
The FAA requires objects over 200 feet tall — i.e. all commercial–scale wind turbines — to be lit. Specific lighting requirements vary from site to site; lights may be red or white, constant or flashing.

Property Values & Tourism

The Renewable Energy Policy project studied 25,000 property transactions in view shed of wind projects, compared to similar sites, and did not find evidence of wind power reducing property values.

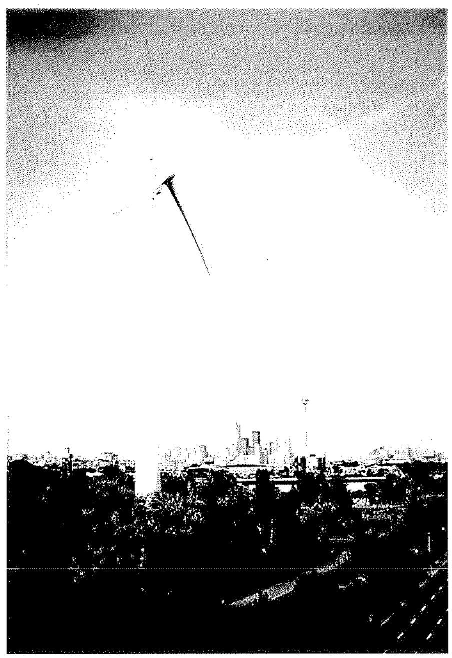
Noise

Wind turbines are relatively quiet. While the way sound carries depends on terrain and wind patterns, wind turbines should, as a rule of thumb, be about three times the hub height or more from residences. From a distance of several hundred feet, wind turbines can be compared to the sound level of a refrigerator.



TV interference

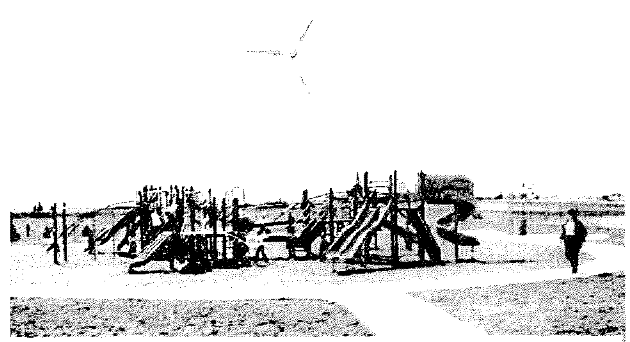
In the past, metal–bladed wind turbines could cause "ghosting" on TV screens. The fiberglass composite of modern wind turbine blades is unlikely to cause any interference with broadcast signals.



Urban-sited community wind, Toronto's WindShare project

Compatibility with other human land uses

Today, modern wind turbines around the world coexist safely with many land uses, including schools, highways, hiking trails and farms. Fact Sheet 4, "Siting in Communities" discusses setbacks that are appropriate under various conditions.



School-yard community wind, Spirit Lake, IA

Photo& graphic credits: Spirit Lake: NREL. Toronto: Toronto Hydro. Sound graphic: AWEA.

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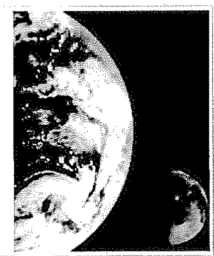
Westborough, MA 01581
508–870–0312
www.mtpc.org/RenewableEnergy/index.htm

15% of babies born in the US had a dangerous level of prenatal exposure to mercury.

Impacts of Fossil Fuel Electricity Generation

Overall air quality in the US has improved since the Clean Air Act of 1970, but our growing appetite for energy continues to harm us and the environment. We make most of our electricity from fossil fuels, emitting:

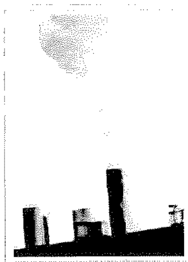
CO_2 Carbon Dioxide



40% of man-made CO_2 emissions are from fossil fuel-fired power plants. Fossil fuel combustion has disrupted the earth's carbon cycles, sending much more CO_2 into the atmosphere than is normal. CO_2 is the predominant greenhouse gas.

Environmental Impacts: Global climate disruption

SO_2 Sulphur Dioxide

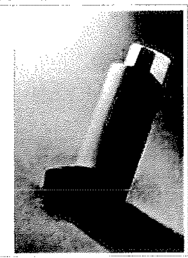


67 % of the USA's SO_2 emissions are from fossil fuel power plants. SO_2 causes acid rain & smog

Health impacts: smog triggers asthma attacks

Environmental Impacts: acid rain harms lakes & streams and can damage trees, crops, historic buildings, and statues. Reduced visibility.

NO_X Nitrogen Oxides



23% of NO_X emissions are from fossil fuel power plants. NO_X causes ground-level ozone (smog) and acid rain.

Health impacts: smog triggers asthma attacks

Environmental Impacts: acid rain, reduced visibility

And...

Mercury - brain damage, fetal damage.
Dioxin - Liver damage, immune deficiency.
Carbon monoxide - poisonous; greenhouse gas.
Particulates, arsenic, lead, cadmium.
Cooling water heats rivers & lakes.
Oil Spills, mountain top removal, ash, sludge, etc.

These are just some of the effects of conventional electricity generation, explaining why all major environmental groups support wind power as one of the tools to reduce our energy's impacts.

For More Information

The National Wind Coordinating Committee has more in–depth information on the impact of wind power: http://www.nationalwind.org/

The Renewable Energy Policy Project studied impacts on land values: http://www.repp.org/articles/static/1/binaries/wind_online_final.pdf

Wind Energy Explained: Theory, Design and Application, Manwell, McGowan, & Rogers, Wiley, 2002

The websites of following organizations discuss the impacts of the generation of electricity: Union of Concerned Scientists, Conservation Law Foundation, American Lung Association, Environmental Defense Fund, and the Environmental Protection Agency.

For the on–line version of this Fact Sheet with the complete set of links, see RERL's website: www.ceere.org/rerl/about_wind/

Credits: Earth & moon photo: NASA. Oil soaked bird photo: Anchorage Daily News. Prenatal mercury exposure reference: Sierra Club.

Renewable Energy Research Laboratory, University of Massachusetts at Amherst

Wind Power: Siting in Communities

Wind Power on the Community Scale

Community Wind Power Fact Sheet # 4

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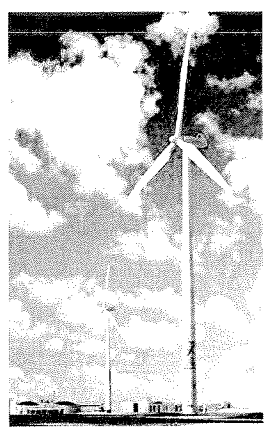
Can my community use wind power?

Towns across Massachusetts are considering wind power, not only because it is one of the cleanest, lowest impact sources of electricity available to us today, but also because a properly sited and well managed wind power project can be a net source of income. This fact sheet introduces the major factors to consider in determining whether your town can benefit from wind power.

Technical / Physical Requirements

Unlike conventional power plants, where a wind turbine is located has a major effect on the amount of energy captured from the wind and electricity produced. The quality of a wind site depends on may things including:

- **Wind speed** – This is the most critical site characteristic and, of course, some places have more wind than others. Typically locations with an annual average wind speeds above about 6 m/s (13 mph) at the hub height are considered. Wind maps are a useful screening tool to estimate the wind speed in an area, but may not accurately represent a specific site.



Community-owned 750 kW wind turbine in Moorhead, Minnesota.

- **Topography, Accessibility** – The site should be open and generally at a higher elevation than the surrounding area. Steep hills or cliffs can create turbulence and should be avoided, however, gradually sloping hills can actually cause an increase in wind speed at the top.

  The topography of a site must also allow access roads to be built for construction and maintenance equipment.

- **Distance to transmission lines and loads** – Electricity generated by a wind turbine must be fed into the electrical grid. Building new transmission lines to move electricity to where it is needed can be very costly, so sites near existing power lines reduce this expense.

  Surface roughness – Tall obstacles on the Earth's surface like trees and buildings can significantly slow the speed of the wind and create turbulence. Turbulence reduces the amount of energy that can be captured and can increase maintenance costs over time. Siting turbines in open fields or in the ocean reduces the effect of surface roughness. Taller towers can also be used to get the rotor above the turbulent zone.

Environmental Considerations

Wind power's predominantly positive environmental impacts (see Fact Sheet 2, Impacts & Issues) do not eliminate the need to consider the local environmental effects of an installation.

Visual impact – Wind turbines are large structures and are usually built in open areas or on ridge lines making them visible from a distance. Some people simply do not like looking at wind turbines. This can be especially true in historically important areas or in places valued for their natural beauty. Siting turbines away from these areas can minimize this impact.

Noise – While noise from wind turbines is minimal, at sites very close to populations it may become an issue. Usually, there are defined limits to how much a new development can increase the sound level. Again, siting turbines away from population centers will reduce this impact.

Birds & Bats – Sites that lie in heavily used bird migration paths or have endangered species in the area may not be appropriate for wind power. For more detail, see page 2 of this fact sheet, and Fact Sheet 3 "Impacts & Issues."

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Searsburg photo: GE Wind Energy

Wind turbines on a ridge, Searsburg, Vermont

Wind in Massachusetts

The best wind power sites in Massachusetts are along the coast and on top of ridge lines in the western and central parts of the state. Wind maps of the state can be used to identify areas of high annual wind. Local terrain effects can also create good sites in other areas of the state that may not be identified in wind maps. The TrueWind website includes a map of New England wind resources.

Spacing & Setbacks

As the wind passes though a turbine energy is extracted causing the wind speed in the wake of the turbine to decrease. When several turbines are built near one another, as in a wind farm, it is important to separate the turbines appropriately to minimize these array losses. Spacing turbines too tightly leads to reduced performance and increased maintenance due to higher turbulence at the downwind turbines. Turbine spacing is expressed in terms of the rotor diameter (RD) of the turbine in consideration. So for instance if a 77 m diameter rotor is used, then 2 RD means 2 x 77 m = 154 m = 505'.

Typically, turbines are spaced 5 to 10 RD apart in the prevailing downwind direction and 2 to 5 RD apart in the crosswind direction, when there is a strongly prevailing direction. Spacing of 2-3 RD might be used along a ridge line. Greater spacing will minimize the losses from each machine, but will reduce the number of machines that can be built in a site.

The setback distance from property lines is determined by local building codes, and typically takes the height of the structure into consideration, e.g. 1.5 times the turbine height. Additionally, state noise policy will typically keep wind turbines about 3 times the hub-height from residences.

Ice throw: Ice is likely to accumulate on ridge-mounted wind turbines in New England, just as it accumulates on trees. The ice sloughs off as the blade flexes. For public safety, ridge-line winter trails may need to be moved away from the base of the tower to a distance of 2-4 times the blade-tip height, depending on the site.

Wind Power Siting for Birds

Modern wind turbines have resulted in an average on 1-2 bird deaths by collision per year per turbine. Good siting practice may reduce this risk further. A "Phase I Avian Risk Assessment" is often performed for a site to assess the risk of both collision and habitat impacts for birds and bats. The assessment for a proposed wind power site typically includes a literature review, interviews with local and regional experts (agency staff, environmental organizations, and local birders), and site visits by a trained wildlife biologist. These sources of information provide an indication of the type and number of birds that are known or suspected to use a project site and the area surrounding that site. This information is used to assess the degree of risk to birds, if any, from wind power development at a particular site. In addition, the concerns of regulators and environmental organizations are determined and incorporated into the risk assessment.

The assessment seeks to determine such factors as:

- Whether the site contains important nesting or foraging areas for federally threatened or endangered birds
- Whether the site has high densities or availability of prey or other habitat attributes that could attract or host large numbers of raptors whose flight or migration patterns put them at risk of collision
- Likelihood of impact of any changes in land use.

The study will then make recommendations for that site based on known avian risk factors at wind power plants in similar habitats. Examples of phase 1 avian risk assessments can be obtained on the Internet. See also Fact Sheet 3 "Impacts and Issues," for a discussion of avian impacts.

(Source: Kerlinger & Curry, various Avian Risk Assessments.)

For More Information

Turbine Siting, from the Danish Wind Industry Association: www.windpower.org/en/tour/wres/siting.htm

Wind Powering America (Dept. of Energy), siting: http://www.eere.energy.gov/windandhydro/windpoweringamerica/ne_siting.asp

The National Wind Coordinating Committee offers various resources, including: Siting Issues for Wind Power Plants, http://www.nationalwind.org/publications/wes/ibrief03.htm, and http://www.nationalwind.org/publications/wes/wes03.htm, and Permitting of Wind Energy Facilities, http://www.nationalwind.org/publications/siting/permitting2002.pdf

Wind Energy Explained: Theory, Design and Application, Manwell, McGowan, & Rogers, Wiley, 2002.

Example of wind turbine icing research: www.msue.msu.edu/cdnr/icethrowseifertb.pdf

Example of an Avian Risk Assessment: http://www.horizonwind.com/images_projects/Arrowsmith/permit/ARR_App_21_Avian_Risk.pdf

University of Massachusetts at Amherst

Wind Power: Resource Assessment

Wind Power on the Community Scale

Community Wind Power Fact Sheet # 5

RERL—MTC Community Wind Fact Sheet Series

In collaboration with the Massachusetts Technology Collaborative's Renewable Energy Trust Fund, the Renewable Energy Research Laboratory brings you this series of fact sheets about Wind Power on the community scale:

1. Technology
2. Performance
3. Impacts & Issues
4. Siting
5. Resource Assessment
6. Wind Data
7. Permitting

   Case Studies

Why assess wind resource?

The amount of power in the wind is very dependent on the speed of the wind. Because the power in the wind is proportional to the cube of the wind speed, small differences in the wind speed make a big difference in the power you can make from it. A 10% difference in speed makes about a 33% change in power.

This gives rise to the primary reason for wind resource assessment. In order to more accurately predict the potential benefits of a wind power installation, wind speeds and other characteristics of a site's wind regime must be accurately understood.

There are also important technical reasons for studying a site's wind characteristics. Wind speeds, wind shear, turbulence and gust intensity all need to be specified when procuring a wind turbine, designing its foundation, etc.

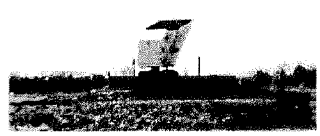
This fact sheet introduces wind assessment methods and technologies. See Fact Sheet #6, "Interpreting Your Wind Resource Data" for more information on wind data itself.

How to assess wind resource

Typically, wind is measured at a height of at least 40 m (131') for a year or more. Equipment designed specifically for wind power is used — weather stations are not sufficient.

Anemometers on a tower: Meteorological towers, or *"met towers"* are the most common and cost effective method. The height of the met tower depends on the topography and nearby trees.

SODAR: a Sonic Detection And Ranging device produces detailed profiles of wind speeds and directions up to hundreds of feet above ground, which is useful, for instance, for understanding wind shear, i.e. how wind speeds vary with height. Because of its expense, SODAR is generally not used for a full year at a single proposed wind site, but when needed, is used for a shorter time and compared with longer term data from anemometers.



A met tower and a SODAR

Wind Maps: computer models can be used to predict annual average wind speed and maps created by these programs, like TrueWind Solutions' maps, are useful as a screening tool for potential wind power sites. However, these maps do not eliminate the need for more precise and thorough wind data collection.

Must the met tower be in the same place as the wind turbine?

Ideally, wind is measured at the exact spot and hub-height of the proposed wind turbine. Realistically, this precision is not usually possible. First, wind is measured at a different height, because most turbine towers are taller than standard met towers.

Second, met towers have different siting requirements than turbines, so they may not be able to fit in the same area. In practice, the data will need some amount of extrapolation. If sufficient data are available, computer models that consider terrain can be used to extrapolate wind speeds measured at the met tower in one place, to a nearby turbine location.

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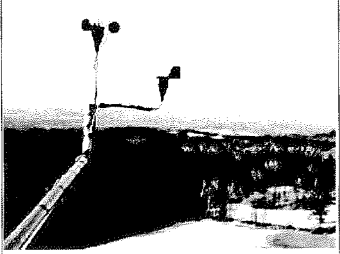
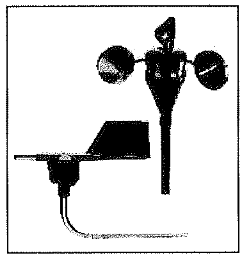


Anemometer & vane in the field.

Met towers & anemometry

Towers:
The most common equipment is a 40 or 50-meter met tower supported by guy wires. This type of tower is a temporary structure. No foundation is required.

In some cases, anemometers can be mounted on existing cell phone towers, although this is not necessarily easy; the instruments must be mounted on long enough booms to minimize "tower shadow" effects, i.e. disturbances in the wind caused by the obstruction. Depending on the cell tower type, a sensor might need to be as far away as 7 times the tower diameter to maintain an error of under 1%. This may result in long and heavy booms.



Anemometer & vane (NRG Systems)

Instruments:
A cup anemometer & a direction vane designed for wind power applications are pictured here. The turning speed of the anemometer indicates the wind speed, and the direction of the vane indicates wind direction.

Data Logger:
The instruments send low-voltage electrical signals to a data recorder at the base of the tower, where ten-minute averages of the speeds and direction are recorded in memory. Some loggers are equipped with internal cell phones that can send the data back to a computer modem; in others, the data-card is swapped out and brought back the office to collect the data.

Siting a met tower

Ideally, wind is measured for at least a year at the proposed site of the wind turbine, using a met tower. Met towers have different siting requirements than do wind turbines, and occasionally the met tower is not put in the same place as the proposed wind turbine site.

The typical 40 and 50-meter (131' and 164') met towers are temporary and transportable. A tower consists of a small base plate that sits on the ground and nested 10-foot sections of 6" or 8" diameter tubing. The tower is supported by guy wires which are held by anchors into the ground. The land must be cleared of trees and shrubs. There must not be any electrical or telephone wires within a distance of 1.5 times the tower height.

Minimum clearing required is given in the following table. More clear space is preferable.

Tower Height	Minimum D *(Guy diameter)*	Minimum L *(Space to lay the tower down)*
40 meter (131')	160 feet	135 feet
50 meter (164')	240 feet	165 feet

To get a feeling for these sizes, compare them to a football field, 160' x 300'.

Some towns require building permits or zoning variances for temporary towers, while others do not.

For More Information

About Wind Data:

Danish Wind Industry Association: www.windpower.org/en/tour/wres/index.htm

US Dept. of Energy: http://www.eere.energy.gov/windandhydro/windpoweringamerica/ne_building_resource.asp

See also Fact Sheet 5, "Interpreting Your Wind Resource Data" and the rest of this fact sheet series: www.ceere.org/rerl/about_wind

Wind Data on the Web:

TrueWind's New England map: truewind.teamcamelot.com/ne/

MTC's work with TrueWind: http://www.masstech.org/RenewableEnergy/green_power/ProjectReportWind1.pdf

Met Tower & Instrument Manufacturers:

NRG: www.nrgsystems.com/

Second Wind: www.secondwind.com/

SODAR Manufacturers:

ART: www.sodar.com/

Aerovironment: www.aerovironment.com/

Wind Energy Explained: Theory, Design and Application, Manwell, McGowan, & Rogers, Wiley, 2002

University of Massachusetts at Amherst

Wind Power: Permitting in Your Community

Wind Power on the Community Scale

Community Wind Power Fact Sheet # 7

RERL—MTC Community Wind Fact Sheet Series

In collaboration with the Massachusetts Technology Collaborative's Renewable Energy Trust Fund, the Renewable Energy Research Laboratory brings you this series of Fact Sheets about Wind Power on the community scale:

1. Technology
2. Performance
3. Impacts & Issues
4. Siting
5. Resource Assessment
6. Wind Data
7. Permitting

    Case Studies

The Permitting Process: Overview

After the wind resource and project site have been determined and the community outreach effort has been started, the next step is to apply for the necessary permits.

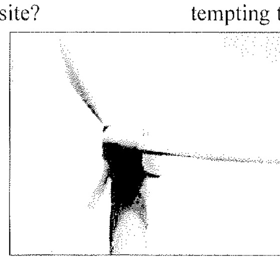
The primary permits needed to construct most community–scale wind power projects will be the local permits: building, zoning, and/or conservation, as applicable to a specific site. Additionally, the project will need to be filed with the FAA and with the operators of the New England electrical grid. Depending on the site, other permits may come into play.

This document outlines these basic permits and also lists other authorities that may have jurisdiction over community–scale wind power projects. Hyperlinks are given in the on-line version, available on the RERL website.

This fact-sheet focuses on land–based community-scale wind power projects with medium or large turbines. For information on permitting offshore projects, contact RERL. This Fact Sheet also does not focus on financial and insurance issues, such as power purchase agreements and turbine certification; refer to Fact Sheets 1 and 2 for more information on these subjects.

General Considerations

- Project goals: Prepare a clear statement about the goals of your wind power project. This statement should, in a few words, be able to represent your project to the world.
- If required, an alternatives analysis focuses attention on:
    - Why is the chosen site the best site?
    - Would other sites be acceptable? Why or why not?
- Supporting Information:
    - The more information you have to support the statements made in your application, the more likely the permit is to be granted and the clearer it will be to the public.
    - Have as many impact studies as possible completed or in progress before submittal or demonstrate that they do not apply.
        - Wildlife, avian, endangered species
        - Wetlands
        - Visual
        - Noise
        - Archeological / historical
        - Transportation and safety
    - Photo simulations are recommended by the permitting agencies and are helpful for the public. The Massachusetts Historical Commission may request photo simulations taken from historic resources, if it has properties within a few miles.



- Electrical: You will also need permits for the areas affected by the electrical cable/line and grid interconnection.
- Project benefits: When writing applications, it is tempting to focus on mitigating harmful impacts. While this is essential, it is also relevant and helpful to quantify the benefits of your project (displacing pollutants, etc.), especially in light of the Commonwealth's air quality goals and renewable portfolio standard.
- Project science: Thorough investigation and characterization of the wind resource will provide good support for your permit application. See the Fact Sheets on resource assessment and wind resource data for more information.
- Installation:
    - Understanding the wind turbine installation process will help you think about land requirements, e.g. for equipment staging.
    - Including a description of the installation sequence and any necessary mitigation is helpful.
- Public relations:
    - Allow time for public comment period.
    - Work with local groups and understand the local political process.

Community–owned wind turbine, at the high school in Hull, MA.

Agencies

That may have Jurisdiction in Community–Scale Wind Projects

The following regulations may apply to a community wind power project at a given site. The order in which permits are issued is typically Local, State, then Federal. Links to most of the forms are included below (in the on-line version of this document).

Local

Regulation / Permit	Authority	Comments
Zoning permit	Town Zoning Board	Some towns have height or setback restrictions that may require a variance.
Special local permit or variance	Town Zoning Board	Needed if zoning bylaws do not yet include wind power projects.
Building permits	Building Inspector	
Board Approval	Planning Board	
Order of Conditions (OOC)	Town Conservation Commission (CC)	This permit is required if wetlands will be altered in any way. The permit application is called a Notice of Intent and is also sent the Mass. Dept. of Environmental Protection. See also Notice of Intent below in State section. If an area of less than 5000 sq. ft. of wetland is altered, then the OOC also serves as the project's Section 401 Water Quality Certificate. If the CC has never dealt with issues related to wind turbines, they may need extra time for education.

State

Regulation / Permit	Authority	Comments	More Information
MEPA Determination: Environmental Notification Form (ENF) or Expanded ENF*	Mass. Executive Office of Environmental Affairs (EOEA)	Must be filed if more than 25 acres of land will be directly altered or other thresholds met. A thorough treatment of this form is recommended.	www.state.ma.us/envir/mepa/index.htm 617-626-1020
MEPA Review: Environmental Impact Report (EIR)	Mass. Executive Office of Environmental Affairs (EOEA)	Unlikely to apply to community-scale projects. Based on the review of the ENF by the Secretary of Environmental Affairs. Automatically required if more than 50 acres of land will be directly altered or other thresholds met.	www.state.ma.us/envir/mepa/index.htm 617-626-1020
Notice of Intent (NOI)	Mass. Department of Environmental Protection (DEP)	Same form as with the local Conservation Commission.	All wetlands forms: http://www.mass.gov/dep/water/approvals/wwforms.htm 800-462-0444
Notice of Intent (NOI) (same as above)	Mass. Natural Heritage and Endangered Species Program	Same form as for the local CC and state DEP. Required if project falls within an "Estimated Habitat" of rare wildlife. Avoid disturbing threatened species.	http://www.mass.gov/dfwele/dfw/nhesp/nhenviro.htm 508-792-7270 ext. 200

Continued on next page...

* The Secretary of Environmental Affairs recommends that proponents of a wind project include and distribute all relevant supporting supplemental information with the ENF form, even if the proponent does not formally choose an "Expanded ENF" option for MEPA review.

State, continued

Regulation / Permit	Authority	Comments	More Information
Conservation and Management Permit	Mass. Natural Heritage and Endangered Species Program	Required if there is any "take" of a state endangered species.	By town: www.state.ma.us/dfwele/dfw/nhesp/nhtown.htm 508-792-7270 ext. 200
General Access Permits	Mass. Dept. of Highways	Needed if road alterations to state roads are required.	617-973-7800
Wide Load Permits	Mass. Dept. of Highways	Possibly needed for transportation of turbine components, construction materials and equipment.	http://www.mhd.state.ma.us/default.asp?pgid=content/permits&sid=about 617-973-7800
Project Notification Form	Mass. Historical Commission	Describe the project and any impact on historic or archaeological properties.	www.state.ma.us/sec/mhc/mhcidx.htm 617-727-8470
Noise control policy (310 CMR 7.10)	Mass. Department of Environmental Protection (DEP)	The policy discourages a broad-band noise level in excess of 10 dB(A) above ambient, or pure tone noise.	www.airandnoise.com/MA310CMR710.html 800-462-0444
EOEA Article 97 Policy Mass General Law Chapter 61	Mass. Executive Office of Environmental Affairs (EOEA)	These govern use of protected land. Compliance with these pieces of legislation is not part of any specific permit, but is necessary for a successful ENF or EIR process. These may be applicable if the project requires access/easements over protected parkland or agricultural land.	www.state.ma.us/envir/mepa/fourthlevelpages/article97policy.htm www.state.ma.us/legis/laws/mgl/gl-61-toc.htm
Massachusetts Clean Waters Act: Section 401 Water Quality Certificate	Mass. Department of Environmental Protection (DEP)	If less than 5000 sq. ft. of wetland is altered, the OOC serves this purpose.	www.mass.gov/dep/bwp/iww/files/314cmr9.htm
NEPOOL Interconnection System Impact Study	ISO New England and the owner of transmission lines at point of interconnection	The impact of the new generating capacity on the existing grid is studied. The Facility Study then determines what, if any, additional electrical components are required for the transmission system.	ISO-New England's information on new or modified interconnections
	Energy Facility Siting Board (EFSB)	The EFSB is primarily concerned with plants of 100 MW or more, but may have jurisdiction over a community wind project if a new transmission line is: - over 1 mile long, or - over 69 kilovolts	www.state.ma.us/dpu/siting/shandbook.htm EFSB: 617-305-3525
Review of Development of Regional Impact (DRI). Town Referral & Application	Cape Cod Commission on Cape Cod Martha's Vineyard Commission in Duke's County	For Cape Cod and Martha's Vineyard only. Most community wind projects will not require a DRI review. Applies if the project meets or exceeds any of the DRI thresholds. If applicable, precedes local permitting.	http://www.capecodcommission.org/regulatory/DRIbrochure.pdf Commission: 508-362-3828
Request for Airspace Review	Mass. Aeronautics Commission (MAC)	While not a permit per se, the MAC should be notified of projects over 200' tall. This process is similar to the federal Part 77 review discussed below.	617-973-8881

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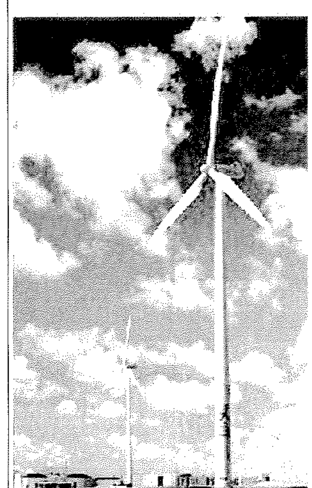

Community–owned wind turbine, in Moorhead, MN

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www.mtpc.org/RenewableEnergy/index.htm

Agencies with Jurisdiction, continued

Federal

Regulation / Permit	Authority	Comments	More Information
Notice of Proposed Construction or Alteration, 7640-1 "Part 77" review	Federal Aviation Administration (FAA)	This form is submitted for all structures at least 200' above ground-level, or within a few miles of an airport (the distance depending on the type of airport). All wind turbines with tip-heights over 200' will need lighting. MassPort (Massachusetts Port Authority) may also be involved if an airport is nearby.	http://forms.faa.gov/forms/faa7460-1.pdf FAA New England: (781) 238-7520
The following federal laws may also be applicable to community-scale wind projects under certain circumstances:			
Habitat Conservation Plan & Incidental Take Permit	US Fish and Wildlife Service	Needed if any federally listed endangered or threatened species will be harmed.	endangered.fws.gov/permits/index.html 603-223-2541
Migratory Bird Treaty	US Fish and Wildlife Service	Forbids the "take" of migratory birds.	603-223-2541
National Pollution Discharge Elimination System (NPDES): Storm Water Notice of Intent	US Environmental Protection Agency (EPA)	Needed if waste water is to be generated during construction, or ground water to be affected. Note that unlike most forms of electricity generation, wind turbines do not use water for power production.	cfpub.epa.gov/npdes/ 202-564-9545
Section 401 and Section 404 of the federal Clean Water Act	U.S Army Corps of Engineers	Most community-scale wind projects will not fall under this regulation. These would apply if fill were discharged into wetlands.	

For More Information

Mass. Executive Office of Environmental Affairs: Mass. Environmental Protection Act: www.state.ma.us/envir/mepa/index.htm and Renewable Energy & Distributed Generation Guidebook http://www.mass.gov/Eoca/docs/doer/pub_info/guidebook.pdf

Examples of state permitting & precedents:

- Hoosac Wind Project Permitting: www.hoosacwind.com/etc6.html
- Hoosac ENF certificate (EOEA # 13143), December 2003: http://www.mass.gov/envir/mepa/downloads/13143enfpdfversion.pdf
- Princeton Municipal Project ENF certificate (EOEA #13229), April 2004: www.state.ma.us/envir/mepa/pdffiles/certificates/13229pdfversion.pdf

For the on–line version of this Fact Sheet with the complete set of links, see www.ceere.org/rerl/about_wind/